METHOD AND APPARATUS FOR A VOLTAGE CONTROLLED START-UP CIRCUIT FOR AN ELECTRONIC BALLAST

BACKGROUND OF THE INVENTION

[0001] The present application relates to ballasts, and power supply circuits for gas discharge lamps. It finds particular application for use with current fed instant and/or rapid start electronic ballasts or power supply circuits and will be described with particular reference thereto. It is to be appreciated, however, that the present application is also applicable to other inverter circuits, and is not limited to the aforementioned use.

[0002] In the late eighties, and early nineties, the lighting industry began to make a shift from passive power and harmonic correction circuits to active power correction and harmonic circuits in the form of active pre-regulators for use in conjunction with electronic lamp ballasts. An advantage of active power factor and harmonic correction via active pre-regulators is that bus voltage variation can be virtually eliminated even though there are still voltage variations on the input line. The visible effect of this change is less variation in lumen output, that is, lamps connected to active pre-regulator circuits exhibit steadier intensities than lamps connected to circuits without active pre-regulation.

[0003] While the use of active pre-regulators has provided improved performance in certain areas, new problems have arisen when these pre-regulators are put into operation with rapid and/or instant-start ballasts or power supply circuits. Particularly, systems employing active pre-regulators require a significant amount of time to reach steady state operating conditions during start-up. This may result in undesirable operating conditions for the gas discharge lamps when the less than steady state operating voltages are passed through the converter section during this transient start-up condition.

[0004] During normal operation, which is a steady state condition, the active pre-regulator will provide a pre-determined DC voltage output, whose value

will be dependent on the circuit design and/or lamp being driven, but in many instances may be up to a 500 V DC output. During the transient start-up condition, the output will be substantially below the desired steady state voltage conditions. Therefore, when operating in rapid and instant start modes the voltage supply will not be at steady state, and may result in an undesirable effect of unacceptable "preheat" or glow periods at this lower voltage. Instant-start lamps are typically specified to be operated in a glow discharge mode for a very short time period, approximately for no more than 100 milliseconds. This is a requirement since longer "preheat" periods will act to shorten lamp life due to excessive electrode erosion during these glow discharge conditions. Additionally, when operating in low voltage (i.e. non-steady state conditions), undesirable visible phenomena such as lamp flickering may occur. Therefore, it is considered desirable to delay the start-up operation of an electronic ballast for instant-start type fluorescent lamps until a pre-determined DC bus voltage has been substantially reached.

[0005] One particular attempt to address this issue is set forth in US patent 5,177,408 to Marques which issued January 5, 1993. This patent disclosed a time delay circuit of an electronic ballast for "instant-start" type fluorescent lamps of the type having an electronic converter powered by an active electronic pre-regulator. The inverter is described as an inductive-capacitive parallel-resonant push-pull circuit or other type of current-fed power-resonant circuit. The start-up circuit may be either a resistor and Zener diode or a resistor, capacitor, and diac network programmable uni-junction transistor circuit connected between the pre-regulator output and an oscillation-enabling input of the inverter. The active electronic pre-regulator is designed so that it takes a pre-determined start-up time to reach steady state operating conditions. This delay device is connected between the pre-regulator and the converter.

[0006] Drawbacks to the above disclosed design exist. For example, to minimize design and development cost, to lower the number of different products (i.e. SKUs), to simplify inventory control, and to address global market needs,

ballasts or power supply circuits having universal input capabilities have become a key selling point. In theory, a device is considered a universal input device if it is capable of operating cooperatively with the various standardized line voltages supplied in different parts of the world. For example, the standard line voltage in the United States is 120 V, in China it is 220 V, and in Europe, 230 V. A universal device would also preferably be able to operate with industrial line voltages which is currently 277 V in the United States.

[0007] The aforementioned US Patent 5,177,408 is, however, dependent on the input line voltage to obtain its time delay. This means to obtain a pre-determined time delay, it would be necessary to take into consideration the line voltage with which the device will be operating. Such a device would not therefore be considered a universal input ballast or power supply. Particularly, if a unit were used with a 120 V input line, the time delay would be different than if that unit were receiving a 230 V input line. Thus, this approach does not take full advantage of active power factor correction control.

BRIEF DESCRIPTION OF THE INVENTION

[0008] In accordance with one aspect of the present application, a lamp inverter circuit is provided. The lamp inverter circuit includes a switching portion that converts a DC signal to an AC signal. Further, the circuit includes an input portion for receiving a line voltage signal, a resonant load portion for receiving a lamp load, and a voltage controlled start-up portion that controls the ignition of the lamp based on a detected voltage.

[0009] In accordance with another aspect of the present application, a method of firing a lamp is provided. An AC line voltage is supplied and converted into a DC bus voltage. A charging capacitor is charged by the bus voltage. A breakdown voltage of a diac is overcome, turning the diac conductive, supplying current to oscillation of the inverter circuit.

[0010] In accordance with another aspect of the present application, a lamp ballast is provided. The lamp ballast includes a switching portion that includes first and second bipolar junction transistors. The ballast also includes a resonant load portion for receiving a lamp, a power factor correction circuit for delivering a bus voltage, and a voltage dependent start-up portion that controls firing of the lamp until the bus voltage ramps up to a pre-determined threshold.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating preferred embodiments and are not to be construed as limiting the invention.

[0012] FIGURE 1 is a block diagram of a lamp system;

[0013] FIGURE 2 is a circuit diagram of ballast inverter circuit included in the lamp system shown in FIGURE 1 with a start up portion operably connected with a high side switch of the inverter circuit;

[0014] FIGURE 3 is a circuit diagram similar to the ballast of FIGURE 2, however the implementation of the start-up portion is on a low side switch of the inverter circuit;

[0015] FIGURE 4a shows the bus voltage over a time sequence for the rapid start electronic ballast according to the present application;

[0016] FIGURE 4b provides a function of the bus voltage versus starting time for a rapid start electronic ballast according to the present application; and

[0017] FIGURE 5 depicts the charge current of capacitor **30** of FIGURE 2 as a function of the bus voltage.

DETAILED DESCRIPTION OF THE INVENTION

[0018] With reference to FIGURE 1, lamp circuit **A** includes a lamp assembly **10** operably connected to a bus voltage sensing and self-oscillating

inverter/starting circuit **12**. The lamp assembly **10** can be a gas discharge lamp or a plurality of gas discharge lamps, such as linear fluorescent or compact fluorescent lamps that operate at a particular frequency or range of frequencies. In one embodiment, the inverter starting circuit **12** is connected to power factor correction (PFC) circuit **14**, such as an active power factor correction circuit which regulates a line voltage, corrects harmonics and supplies a bus voltage to inverter starting circuit **12**. It is to be understood that PFC circuit **14** may provide passive power correction in an alternate embodiment. An AC voltage source **16** supplies an alternating current signal to the PFC circuit **14**. The voltage source **16** can deliver a wide range of signals. Currently in the United States, the standard wall socket delivers a 120 V RMS voltage. The standard line voltage in China is 220 V, and Europe is higher, at about 230 V. Other sources, such as ones used for more industrial applications can deliver voltages of 277 V or higher. In one embodiment, the resulting bus voltages produced by PFC **14** range from 169 V (with a 120 V input) to 390 V (with a 277 V input), or more. The PFC circuit **14** can accept an input line voltage in the above disclosed range, in addition to accommodating higher or lower input voltages. Active and/or passive power factor correction circuits of this type are well known in the art, and therefore a detailed description of their operation is not undertaken here.

[0019] With reference to FIGURE 2, illustrated is a detailed view of the inverter starting circuit **12** in a current fed half bridge inverter implementation. In order to convert a DC bus signal into an AC signal, a first transistor **20** and a second transistor **22** alternate between periods of conductivity and periods of non-conductivity, out of phase with each other. That is, when the first transistor **20** is conductive, the second transistor **22** is non-conductive, and vice-versa. The transistors **20, 22** are part of a switching portion of the inverter circuit **12**. The action of alternating periods of conduction of the transistors provides an AC signal to the lamp assembly **10**. In the embodiment illustrated in FIGURE 2, the transistors are bipolar junction transistors (BJTs), but it is to be understood the

concepts of the present application may be incorporated in other inverter circuits, such as known in the art. For example, the following descriptions may be implemented with BJTs in both half-wave current fed ballasts and push-pull type current fed electronic ballasts, among others.

[0020] In this embodiment, each transistor **20, 22** has a respective base, (B) emitter, (E) and collector (C). The voltage from base to emitter on either transistor defines the conduction state of that transistor. That is, the base to emitter voltage of transistor **20** defines the conductivity of transistor **20** and the base to emitter voltage of transistor **22** defines the conductivity of transistor **22**. In the illustrated embodiment neither of the transistors **20, 22** are conductive when current is initially supplied by the PFC circuit **14** to the inverter starting circuit **12**. As will be expanded upon below, a start-up portion **24** of the inverter circuit prevents current from being supplied to the transistors **20, 22** before the bus voltage from the PFC circuit **14** reaches a predetermined threshold voltage. The start-up portion includes Zener diode **26**, diode **28**, capacitor **30**, and diac **32**.

[0021] The potential difference across capacitors **34** and **36** is equivalent to the bus voltage from the PFC circuit **14**. In one embodiment, capacitors **34** and **36** are of equal value, so that the voltage across capacitor **34** is the same as the voltage across capacitor **36**. In parallel with capacitors **34** and **36** are resistors **38, 40**, and **42**. Resistors **38** and **40** form a voltage divider at node **44** and current is supplied to the start-up portion **24** through voltage divider **38, 40**.

[0022] When power is first applied to the inverter starting circuit **12**, Zener diode **26** and diode **28** prevent any significant current from passing through start-up portion **24**. As the bus voltage ramps up, after power is initially supplied to inverter starting circuit **12**, a portion of the circuit current charges capacitors **34** and **36**, other current charges snubber capacitor **46**, and the remaining current flows through resistors **38, 40**, and **42**. Initially, because the bus voltage is divided by resistors **38** and **40**, a breakdown voltage of Zener diode **26** is not reached, and Zener diode **26** prevents current from passing through start-up portion **24**.

Eventually, the bus voltage from PFC **14** ramps to a level where the potential at node **44** is greater than the breakdown voltage of Zener diode **26** turning Zener diode **26** conductive, supplying increased current levels to start-up portion **24**, and more specifically, to capacitor **30**. In the illustrated embodiment, the breakdown voltage of Zener diode **26** is between 64.5 and 71.5 V, and preferably 68 V.

[0023] Once Zener diode **26** turns conductive (from left to right in FIG. 2) capacitor **30** begins charging. At this point, current is being supplied to start-up portion **24**, but diac **32** prevents the base of transistor **20** from becoming conductive in the collector-emitter direction. As the bus voltage continues ramping up, capacitor **30** collects more charge, and eventually reaches a potential to overcome the breakover voltage of diac **32**. When the breakover voltage is reached, transistor **20** turns conductive, wherein inverter starting circuit **12** begins to oscillate, and after approximately 0.7 seconds, lamp assembly **10** is ignited.

[0024] After the breakover voltage of diac **32** is reached, capacitor **30** no longer has an opportunity to continuously collect charge. Current flows directly from node **44** to capacitor **30**, since transistor **20** is conductive after diac **32** breaks down. Diode **28** provides a path to allow capacitor **30** to discharge, once per cycle. The inverter starting circuit **12** now operates as is typical, with no further activity from the start-up portion **24**.

[0025] With continuing attention to FIGURE 2, switching transistors **20, 22** are driven by respective drive circuits **48, 50**. Drive circuit **48** incorporates diode **52**, resistor **54** combination supplied via coupling of winding **58**. Drive circuit **50** incorporates diode **60**, resistor **62** combination, supplied via coupling of windings **66**. Lamp assembly **10** is provided with power from inverter starting circuit **12** by a coupling between windings **68** and **70**, where winding **70** has a capacitor **72** across its primary winding and are considered resonant load components.

[0026] In the event of an over voltage occurring during lamp start-up or sudden load removal, power Zener diodes **74** and **76** will clamp the voltage to protect the BJTs from over voltage damage.

[0027] With continuing attention to FIGURE 2, breakover voltage of diac **32** is chosen to be an optimal bus voltage for starting the inverter circuit and ignition voltage of lamp assembly **10**. In the illustrated embodiment, the breakover voltage of diac **32** is chosen to be such that when the bus voltage (the voltage across capacitors **34** and **36**) reaches a pre-determined value, for example about 390 V, diac **32** reaches its breakover voltage. Stated differently, start-up portion **24** detects when the bus voltage reaches the preferred firing voltage by virtue of the chosen breakover voltage of diac **32**. In the illustrated embodiment, the breakover voltage of the diac **32** is between 20 V and 40 V, and preferably about 32 V.

[0028] It is to be understood the above description that applies to first transistor **20** is also applicable to second transistor **22**. That is, as shown in FIGURE 3 in an alternate inverter starting circuit **12'** embodiment, the start-up portion **24** is connected to second transistor **22**, and it, instead of first transistor **20**, would initiate oscillations. Components having similar operation and use as components in FIGURE 2 are similarly numbered as in FIGURE 2.

[0029] The firing voltage is chosen to be about 300 V or greater for rapid start ballasts.

[0030] FIGURE 4a provides a graphed time sequence of a rapid start electronic ballast incorporating inverter starting circuit **12** of the present application. As seen from this figure, the sequence includes three distinct transitions. Fo a 120 V input line, from turn-on (0) to t_0 the bus voltage transitions from its starting voltage (e.g. 169 V) to a preferred pre-heat voltage (e.g. 390 V). The time duration to t_0-t_1 is a pre-heat time (e.g. steady 390 V), and from t_1 to t_2, the bus voltage ramps up to its steady state (e.g. 500 V). Turning attention to FIGURE 4b, depicted is a chart showing inverter starting time for a rapid start electronic ballast incorporating inverter starting circuit **12**. Viewing FIGURES 4a and 4b together emphasizes the starting time is controlled by the bus voltage of the circuit. For example if the bus voltage is less than 300 V, the lamp will take approximately 10 seconds to start, however, when the bus voltage is 300 V or

more, the start time is reduced to approximately 40 milliseconds. FIGURE 4b illustrates the voltage dependency of the circuit, and emphasizes that operation to start the circuit is not a time dependent factor but is rather a voltage controlled concept. There is no pre-determined time following energization that the oscillations will begin. Rather, in the present design, following energization of the circuit, as long as the bus voltage is below a certain value (e.g. 300 V) there will, ideally, be no oscillations and only when the voltage is at or above the breakover voltage (e.g. 300 V) will the oscillations begin. Thus it is shown the starting of the circuit is controlled by the value of the bus voltage.

[0031] Turning now to FIGURE 5, depicted is operation of charge capacitor **30** of FIGURE 2, which illustrates its two distinct charging rates. Charge capacitor **30** will always have an amount of stored energy to be used for the breakover of diac **32**. As seen, when the bus voltage is over 300 V, capacitor **30** charges at a very quick rate, and when below 300 V bus voltage, capacitor **30** is being charged only due to leakage current. Particularly, when the bus voltage is less than 300 V, Zener diode **26** never turns conductive in its reverse direction, and allows only a leakage current **80** to charge capacitor **30**. After the bus voltage reaches 300 V, a significantly higher charging current **82** is available to capacitor **30**.

[0032] Another consideration in selecting the threshold voltage is the starting bus voltage. For a 120 V line input, the output bus voltage ramps up from about 169 V. For a 277 V line input, the output bus voltage ramps up from about 390 V. As stated earlier, the start time (FIGURE 4b) is about 40 milliseconds at 390 V. After lamp assembly **10** is ignited, the bus voltage continues to ramp up to steady state operating voltage **V**. Thus, one exemplary firing voltage is 390 V, because it is greater than the 300 V required for mode transition, is less than common steady state operating voltages, and fires the lamp as soon as possible, before the bus voltage reaches steady state. Of course, greater or lesser firing voltages can be chosen, for example in some applications the bus voltage may

experience an overshoot during start-up, based on known line voltages and desired universality of the inverter.

[0033] Thus, from the foregoing, it is shown (FIGURES 2 and 3) are two implementations of a new starting circuit in conjunction with a current fed, half-bridge inverter circuit. The main bus voltage is sensed by a three resistor divider circuit. A portion of the bus voltage is applied to a Zener diode and a charging capacitor. When the voltage reaches a pre-determined level, the Zener diode breaks down, allowing the charging capacitor to charge. A diac then breaks down, causing the self-oscillating inverter to be triggered. A diode prevents the charging capacitor from charging, allowing it to discharge every half-cycle, when a first transistor is on. The component values are selected such that the Zener breakdown voltage is at least double the diac breakdown voltage, or higher. Possible applications of the present invention include General Electric's 4 ft. and 8 ft. T12 and T8 electronic lamp ballasts.

[0034] Exemplary component values for the circuits of FIGURES 2 and 3 are as follows:

Part Description	Part Number	Nominal Value
Lamp Assembly	10	40 Watts
Line Voltage	16	120-277 Volts
First Transistor	20	BJT SPB 11NM60
Second Transistor	22	BJT SPB 11NM60
Bus Capacitor	34	33 μf
Bus Capacitor	36	33 μf
Bus Resistor	38	400 kΩ
Bus Resistor	40	620 kΩ
Bus Resistor	42	1 MΩ
Zener Diode	26	68 V
Diode	28	UF 4007
Capacitor	46	1.2 nf
Charging Capacitor	30	0.1 μf
Diac	32	HT-32
Zener Diode	74	P6KE440A

Zener Diode	76	P6KE440A
Inductive Winding	56	5 mh
Inductive Winding	64	5 mh
Base Diode	52	1N5817
Base Diode	60	1N5817
Base Resistor	54	75 Ω
Base Resistor	62	75Ω
Inductive Winding	70	0.85 Henries
Inductive Winding	68	1.27 Henries
Capacitor	72	12 nf

[0035] The invention has been described with reference to the preferred embodiment. Modifications and alterations will occur to others upon a reading and understanding of the preceding detailed description. It is intended that the invention be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.